NAVAL POSTGRADUATE SCHOOL
Monterey, California

UNDERSTANDING "UNDERSTANDING" FLOW
FOR NETWORK-CENTRIC WARFARE:
MILITARY KNOWLEDGE-FLOW MECHANICS

by

Mark E. Nissen

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Network-centric warfare (NCW) emphasizes information superiority for battlespace efficacy, but it is clear that the mechanics of how knowledge flows are just as important as those pertaining to the networks and communication systems used to transmit data and information. Unfortunately, with the strong presumption that knowledge is distinct from data and information, knowledge-flow mechanics in the warfare context are not well understood; even the term *knowledge* is used in conflicting ways (e.g., to describe *information* flows) by NCW experts, operational personnel and developers of military doctrine. Mapping key concepts from technologically enabled business models—on which NCW is based in large part—to the military, we substitute the term *understanding flow* when discussing the mechanics of how knowledge flows in the NCW context. In one respect, this mapping and terminological substitution enable us to move forward and model knowledge-flow mechanics in a manner that is consistent with the operational Navy's lexicon; in another respect, however, it is clear that Navy lexicon does not yet include the term *understanding flow*. Hence, naval conceptualization of NCW may be missing a vital element.

Informed by recent advances in knowledge-flow theory, the research described in this technical report develops a four-dimensional model of understanding-flow mechanics. This multidimensional model enables a novel capability to recognize a variety of understanding-flow patterns found in the military enterprise, to distinguish such patterns from their counterparts pertaining to information and data, and to enhance the speed and efficiency of NCW understanding flows. Just as understanding the mechanics of electrical flow is critical to developing useful electronic devices (e.g., amplifiers, integrated circuits), and understanding airflow mechanics is essential for designing useful aircraft equipment (e.g., engines, wings), understanding the mechanics of understanding flow is critical to conceiving useful NCW systems (e.g., "knowledge engines," "knowledge amplifiers"). To help make understanding-flow concepts and applications concrete, we employ our model of understanding flow to Navy-led, joint task force (JTF) operations at sea. The result is an increased understanding of understanding flow for network-centric warfare, which can be employed to guide the design of useful information systems, understanding-flow devices and business processes for military operations.

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NETWORK-CENTRIC WARFARE AND UNDERSTANDING FLOW

Network-centric warfare (NCW) represents a revolutionary concept and dramatic departure from the long-practiced platform-centric warfare doctrine and methods it is expected to replace. Although many proponents characterize NCW as the "most important RMA [revolution in military affairs] in the past 200 years" (Cebrowski and Gartska 1998, p. 29), our understanding of this novel and compelling approach to military warfare remains primitive. For instance, NCW emphasizes speed for tactical advantage, but such speed pertains as much to decision-making, command and control as it does to maneuver; NCW further emphasizes information superiority for battlespace efficacy, but it is clear that much more is included than just the networks and communications infrastructure—impressive as it has become for a sea-based environment—associated with flows of information (and data).

By mistake, some have focused on communication networks, not on warfare or operations where the focus should rightly be. Networks are merely a means to an end; they convey "stuff" from one place to another and they are the purview of technologists" (Alberts et al. 1999, p. 92).

Indeed, without computer automation and decision aids, simply increasing the speed of (data and) information flows can quickly overwhelm even the most capable commanders. Further, the U.S. Navy understands that knowledge is key, for the warfighter must *know what to do* with information. Consider a seasoned (e.g., with 20 years' experience) Navy Captain (i.e., O-6) and a newly commissioned Ensign (i.e., O-1) in the information center of a ship underway and in combat. One can provide exactly the same data and information (e.g., through displays, reports, observations, staff members) to both naval officers, but the more experienced person would be expected to exhibit superior performance (e.g., in terms of decision-making speed, thoroughness of observations, efficacy of actions). Since the data and information presented to both officers is identical, the differential performance must be attributable to the difference in *knowledge* possessed by the two people. Such experience-based knowledge differential helps to explain why Navy Captains are authorized to command naval vessels whereas Ensigns are not, regardless of how technically sophisticated the ships' information systems may be.

The realization that knowledge is key to NCW is made explicit through the concept *battlespace knowledge*. We even find a whole published volume devoted to the construct *dominant battlespace*

knowledge (Johnson and Libicki 1995). Consider, for instance, the following excerpt from a recent book on NCW (Alberts et al. 1999, p. 126).

The key to understanding the roles and the relationships among battlespace entities is to focus on processes that turn raw data into information and information into knowledge. ... battlespace knowledge consists of tacit information ... requires interpretation ... can seldom be transferred quickly and easily. ... Examples include capabilities and tactics of an adversary, local customs and intent. ... Battlespace knowledge is a people-centric capability.

Interestingly, NCW is based in large part on, and in many respects parallels, advances in business models enabled by information technology (Cebrowski and Gartska 1998). From current research in the business domain, we understand that knowledge is not evenly distributed through any enterprise—particularly not those very large, geographically distributed ones such as global manufacturing firms, telecommunications companies and naval forces—and rapid, efficient knowledge flows are critical to efficacy in business and warfare alike. The research described in this technical report addresses the enhancement of enterprise knowledge flows directly, and it develops and applies a novel model for identifying and classifying various knowledge-flow patterns that can be observed in the modern enterprise. The analysis of such knowledge-flow patterns is useful to inform the design of information systems and business processes that increase enterprise performance, and we focus explicitly on performance of the military enterprise through NCW.

This focus on the *flow* of knowledge reflects an inherently dynamic view, one that draws its rationale from the physical sciences, in which a multitude of useful devices (e.g., computers, aircraft) are designed and developed through principles and methods of engineering. In sharp contrast, many information systems and business processes employed in business and military enterprises are designed and developed through trial and error, clearly one of the least efficient approaches known. Imaging trying to develop useful electronic devices (e.g., amplifiers, integrated circuits) without possessing a thorough understanding of how electricity flows, or expecting to develop useful aviation devices (e.g., engines, wings) without thorough knowledge of how air flows. Analogously, what would lead one to believe that useful business and military devices (e.g., knowledge amplifiers, knowledge engines) can be developed without a thorough understanding of how knowledge flows?

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Mapping Military and Business Concepts

Before we can effectively address how to enhance knowledge flow to increase the efficacy of NCW, it is important to overcome differences between military and business conceptualizations of knowledge flow. Specifically, fundamental terms such as *data, information* and *knowledge* have conflicting differences in terms of meaning, definition and use between these environments; we also find that NCW experts, operational personnel and developers of military doctrine in the Navy inadvertently confuse important concepts and incorrectly interchange key terms in a manner that impairs effective communication and obstructs the principled design of useful information systems and business processes.

The Military uses a model called the Cognitive Hierarchy (NDP6 1995), which outlines a four-tier hierarchy interrelating raw data, processed data, knowledge and understanding. At the "bottom" of this hierarchy, we find *raw data*, which are abundant (e.g., through sensor input) and easily transmitted via automated systems but not particularly useful on their own. Lying just "above" this hierarchical level, we find *processed data* (e.g., through sensor fusion, displays), which are more useful but less abundant and more difficult to transmit automatically. Further "up" in this hierarchy, we find *knowledge*, which in this context pertains to *what* is happening (e.g., situational awareness) in a military environment; because most of the highly valued knowledge in an enterprise is tacit, its "transmission" takes place in the minds of people and via interpersonal communication, which makes such knowledge relatively difficult to convey and share (e.g., a Common Operational Picture). The "top" position of the hierarchy is occupied by *understanding*, which pertains to *why* things are happening as they are (e.g., forces amassing for coordinated attack); here, as understanding represents an even more tacit capability of people, it is very difficult to share and slow to flow through an enterprise.

Insightful as this cognitive hierarchy model may be, however, the same kind of hierarchical model is also employed in the business environment, but with many of the same terms having different meanings. Compare the knowledge-information-data (KID) model, illustrated in Figure 1, that is common in the business domain (Nissen 2002). Here, we find a similar hierarchical relationship with *data* on the "bottom," but this latter model has only three levels, with *information* in the "middle" and *knowledge* on "top." In this business model, *data* refers to raw facts that are high in abundance but low in terms of actionability (i.e., one's ability to take useful actions, such as correct decisions or appropriate behaviors).

Information builds upon data to provide context and become more actionable, but useful information is scarcer than data. *Knowledge* builds upon information to enable action directly, but in comparison with either data or information, knowledge is quite scarce in the enterprise. Notice in this latter business model that we can only speculate as to what useful concept, if any, may lie "above" *knowledge* (e.g., wisdom, enlightenment).
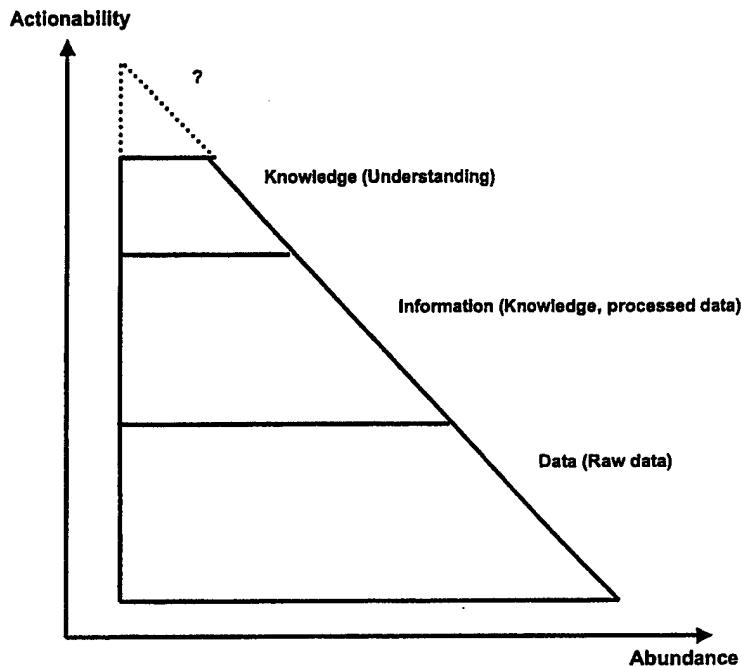
Figure 1. KID Model with Business/Military Conceptual Mapping

Through analysis of the reference literatures (i.e., naval doctrine, business models), we can map the two hierarchical models through the following three steps: 1) *Raw data* in the military context maps cleanly to *data* in the business model; 2) *processed data and knowledge* in the military context map approximately to *information* in the business model; and 3) *understanding* in the military context maps quite well to *knowledge* in the business model. This mapping is depicted (parenthetically) in Figure 1. Therefore, to adapt our emerging models and tools pertaining to knowledge flow in the business environment and apply them to NCW in the military context, we need to observe the conceptual mapping

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delineated in the figure. Thus, throughout this report, where current research on enhancing *knowledge-flow* dynamics is applied to NCW, we substitute the term *understanding flow* to depict the military context of this work; that is, this technical report explicitly addresses understanding understanding flow for NCW.

The balance of the technical report is organized as follows. In the next section, we provide conceptual background for understanding understanding flow, which is followed by development of a model to describe and explain understanding-flow dynamics. To help make understanding-flow concepts and applications concrete, we employ our model to Navy-led, joint task force (JTF) operations at sea. The report closes with key conclusions and topics for continued research along these lines.

UNDERSTANDING UNDERSTANDING FLOW

This section summarizes key background work pertaining to understanding flow. The section begins by drawing from the emerging knowledge management literature. Research to integrate re-engineering with knowledge management is then covered, after which we outline the theoretical underpinnings used to advance the modeling of understanding flow through this study.

Knowledge Management Literature

The emerging phenomenon of knowledge management (KM) is generating substantial attention. Miles et al. (1998, p. 281) caution, however, "knowledge, despite its increasing abundance, may elude managerial approaches created in 20th century mindsets and methods." In fact, knowledge is proving difficult to manage, and knowledge work has been stubbornly resistant to re-engineering and process innovation (Davenport 1995). For one thing, Nonaka (1994) describes knowledge-creation as primarily an individual activity, performed by knowledge workers that are mostly professional, well educated and relatively autonomous, often with substantial responsibility in the organization. They tend to seek and value their relative autonomy and often resist perceived interference by management in knowledge-work activities (Davenport et al. 1996).

Moreover, substantial important knowledge is tacit (Polanyi 1967), unstructured (Nonaka 1994) and external to the organization (Frappaolo 1998). This can greatly impede the identification, acquisition, interpretation and application of such knowledge. Also, corporate knowledge has historically been stored on paper and in the minds of people (O'Leary 1998). Paper is notoriously difficult to access in quantity and

keep current on a distributed basis, and knowledge kept in the minds of workers is vulnerable to loss through employee turnover and attrition.

The KM literature has been surging lately, particularly with recent contributions through several scholarly publications. For instance, we now have a variety of perspectives on knowledge transfer, including the understanding of context (Augier et al. 2001), mentoring and storytelling (Swap et al. 2001), and situations promoting knowledge reuse (Markus 2001). As another instance, researchers are helping us to understand the importance of narrative (Linde 2001), types of knowledge-based innovation (Cardinal et al. 2001), organizational knowledge contingency factors (Becerra-Fernandez and Sabherwal 2001), and situated learning (Nidumolu et al. 2001). Further, researchers are fostering KM research agendas (Grover and Davenport 2001) as well as taxonomies to help organize KM strategies (Earl 2001), and organizational factors such as capabilities (Gold et al. 2001) and perceptions of ownership in terms of information and expertise (Jarvenpaa and Staples 2001) are now taking shape in terms of understanding.

For the purposes of this report, three important concepts from the KM literature are briefly summarized below: 1) extant information technology, 2) knowledge-based systems, and 3) knowledge management life cycle. The corresponding discussion helps frame current thinking and activity in KM and is specifically focused on concepts employed in the present investigation.

Extant Information Technology
Extant information technology used to support KM is limited primarily to conventional database management systems (DBMS), data warehouses and mining tools (DW/DM), intranets/extranets, portals and groupware (O'Leary 1998). Arguably, just looking at the word "data" in the names of many "knowledge management tools" (e.g., DBMS, DW/DM), we are not even working at the level of information, much less knowledge. And although (esp. Web-based) Internet tools applied within and between organizations provide a common, machine-independent medium for the distribution and linkage of multimedia documents, extant intranet and extranet applications focus principally on the management and distribution of information, not knowledge per se. Although a great improvement over previous stove-piped systems, islands of automation and other IS maladies, as Nonaka (1994, p. 15) states, such "information is [just] a flow of messages," not knowledge.

Along these same lines, groupware offers infrastructural support for knowledge work and enhances the environment in which knowledge artifacts are created and managed, but the flow of knowledge itself remains indirect. For instance, groupware is widely noted as helpful in the virtual office environment (e.g., when geographically dispersed knowledge workers must collaborate remotely) and provides networked tools such as shared, indexed and replicated document databases and discussion threads (e.g., Lotus Notes/Domino applications), as well as shared "white boards," joint document editing capabilities and full-duplex, multimedia communication features. These tools serve to mitigate collaborative losses that can arise when rich face-to-face joint work is not practical or feasible. But supporting (even rich and remote) communication is not sufficient to guarantee a flow of knowledge.

Knowledge-Based Systems

Construction and employment of knowledge-based systems (KBS) can make knowledge explicit and its application direct. Key KBS technologies include applications such as expert systems and intelligent agents, along with infrastructure and support tools such as ontologies, knowledgebases, inference engines, search algorithms, list and logic programming languages and a variety of representational formalisms (e.g., rules, frames, scripts, cases, models, semantic networks). Much deeper than just their names' sake, KBS are predicated on the capture, formalization and application of strong domain knowledge, and use of KBS for knowledge organization and distribution is well known, widespread and now the subject of textbook application (Russell and Norvig 1995, Turban and Aronson 2001).

Unlike the extant IT tools noted above, the substance of KBS is knowledge itself—not just information or data—and KBS are designed to interpret and apply represented knowledge directly. These capabilities and features make KBS distinct from most classes of extant IT applications presently employed for KM (Smith and Farquhar 2000). However, expert system development—through classic knowledge engineering—requires explicit capture and formalization of tacit knowledge possessed by experts. This is just the kind of tacit knowledge that researchers (e.g., Leonard and Sensiper 1998, p. 112) stress "underlies many competitive capabilities," but such knowledge has long been known as being "hard to capture."

Knowledge Management Life Cycle

Nissen et al. (2000) observe a sense of process flow or a life cycle associated with knowledge

management. Integrating their survey of the literature (e.g., Despres and Chauvel 1999, Gartner Group

1999, Davenport and Prusak 1998, Nissen 1999), they synthesize an amalgamated KM life cycle model as

outlined in Table 1. Briefly, the "create" phase begins the life cycle, as new knowledge is generated within

an enterprise. The second phase pertains to the organization, mapping or bundling of knowledge. Phase 3

addresses some mechanism for making knowledge formal or explicit, and the fourth phase concerns the

ability to share or distribute knowledge in the enterprise. Knowledge application for problem solving or

decision making in the organization constitutes Phase 5, and a sixth phase is included to cover knowledge

evolution, which reflects organizational learning through time.

Table 1. Knowledge Management Life Cycle Models (Adapted from Nissen et al. 2000)

Model	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Despres and Chauvel	Create	Map/bundle	Store	Share/transfer	Reuse	Evolve
Gartner Group	Create	Organize	Capture	Access	Use	
Davenport & Prusak	Generate		Codify	Transfer		
Nissen	Capture	Organize	Formalize	Distribute	Apply	
Amalgamated	Create	Organize	Formalize	Distribute	Apply	Evolve

Drawing further from this research on life cycle models, the authors note that coverage of extant

information systems and business practices across these life cycle phases is patchy. For instance, numerous

systems and practices are identified from the literature, but they support only three of the six life cycle

phases: knowledge organization, formalization and distribution. Alternatively, relatively few counterpart

systems and practices are found to correspond with the other three phases: knowledge application,

evolution and creation. We thus observe a relative abundance and dearth of systems and practices available

to support these respective phases of the KM life cycle.

Re-engineering and Knowledge Management Integration

Substantial integration of knowledge management with re-engineering has been observed in current

practice, as companies realize the direct connection between KM and knowledge-work process innovation

(Davenport et al. 1998). In their study of more than thirty KM efforts in industry, Davenport et al. (1996)

note the practice is "fundamentally change management projects." And emerging theory of knowledge

creation and management has a dynamic, distinctly process-oriented flavor (see esp. Nonaka 1994). Ruggles (1998) goes so far as to suggest a primary objective of the practice is to assess the impact of KM as a process, fundamentally a proposition of re-engineering.

However, as learned through the painful, expensive and failure-prone "first wave" of re-engineering (Cypress 1994), simply inserting information technology (IT) into a process in no way guarantees performance improvement. Indeed, many otherwise successful and effective firms experience process *degradation* as the result of re-engineering (cf. Caron et al. 1994, Hammer and Champy, 1993). This point is underscored by Hammer (1990), who colorfully refers to such practice as "automating the mess" (e.g., making a broken process simply operate—broken—faster).

Drawing all the way back to Leavitt (1965) and others (cf. Davenport 1993, Nissen 1998), new IT needs to be integrated with the design of the *process* it supports, which includes consideration of the organization, people, procedures, culture and other key factors, in addition to technology. Given that many KM projects now revolve around IT implementation (e.g., intranets/extranets, Web portals, groupware; cf. Nissen et al. 2000), re-engineering and knowledge management even appear to be sharing some of the same mistakes.

Horizontal and Vertical Processes
Building upon the research above, we begin to characterize a powerful interaction between the flow of work (i.e., workflow; cf. Georgakopoulos et al. 1995) and the flow of knowledge (i.e., knowledge flow) in an enterprise. Drawing from Nissen and Espino (2000), we refer to these respective flows as *horizontal processes* and *vertical processes*, as conceptualized in Figure 2. Briefly, the two horizontal directed graphs in the figure delineate separate instances of a work process (e.g., steps 1 – 6 as performed at different points in time, space, organization). The graph at the top of this figure represents one particular instance (e.g., performed at a specific point in time, location, organization) of this notional process, and the graph at the bottom represents a *different* instance (e.g., performed at a separate point in time, location, organization).

Whereas both horizontal graphs represent the flow of *work* through the enterprise, however, the vertical graph represents a complementary set of processes responsible for the flow of *knowledge*. As noted above, knowledge is not evenly distributed through the enterprise, yet management is interested in

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performance, consistency and effectiveness *across* various workflows. This requires the associated

knowledge (e.g., process procedures, best practices, tool selection and usage) to flow across time, space

and organizations. Such cross-process activities are seen as driving the flow of knowledge—as opposed to

the flow of work—through the enterprise, and it is upon these vertical process flows that we concentrate in

this research.
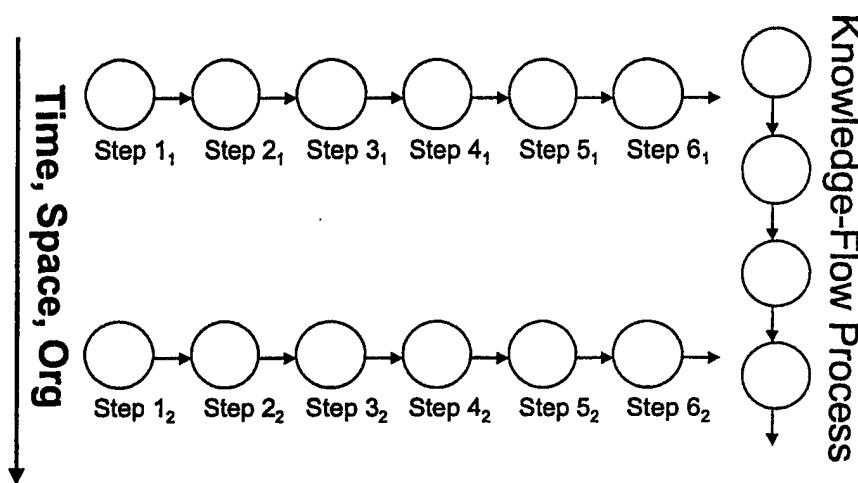
Figure 2. Horizontal and Vertical Processes

Current Knowledge-Flow Theory

One of the best-known theoretical treatments of knowledge flow to date stems from Nonaka (1994) in the

context of organizational learning. This work outlines two dimensions for knowledge: 1) *epistemological*,

and 2) *ontological*. The epistemological dimension depicts a binary contrast between explicit and tacit

knowledge. Explicit knowledge can be formalized through artifacts such as books, letters, manuals,

standard operating procedures and instructions, whereas tacit knowledge pertains more to understanding

and expertise contained within the minds of people. The ontological dimension depicts knowledge that is

shared with others in groups or larger aggregations of people across the organization. Although this

aggregation of organizational units appears arbitrary, in the enterprise context, it could clearly apply to

small teams, work groups, formal departments, divisions, business units, firms and even business alliances or networks.

Epistemological
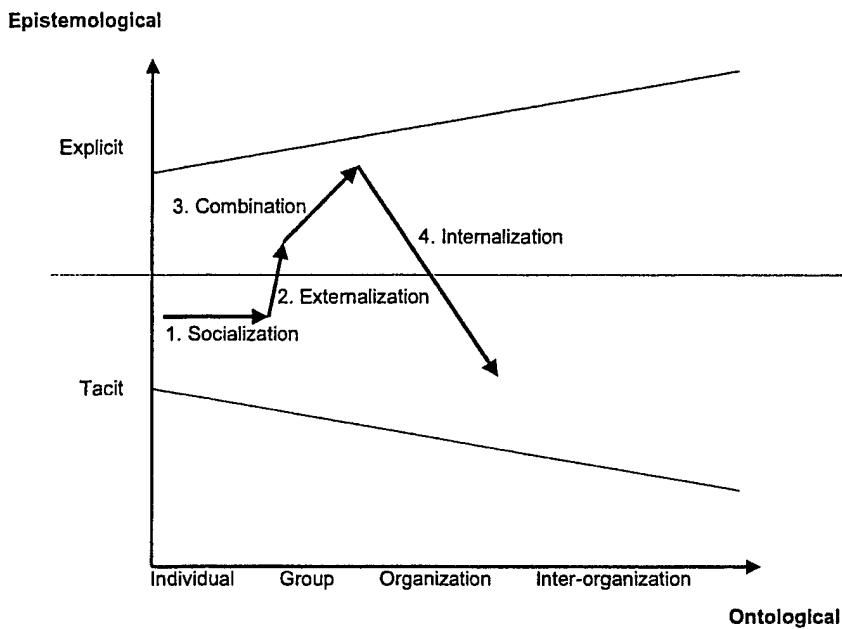
Figure 3. Nonaka Knowledge Flow Theory
(Adapted from Nonaka 1994)

As depicted in Figure 3, Nonaka uses the interaction between these dimensions as the principal means for describing knowledge flow. This flow is roughly characterized through four steps. First, Nonaka asserts that new knowledge is created only by individuals in the organization and is necessarily tacit in nature. The first flow of knowledge is then theorized to occur through a process termed *socialization*, which denotes members of a team sharing experiences and perspectives, much as one anticipates through communities of practice. This first socialization flow is noted as vector #1 in the figure and corresponds to tacit knowledge (i.e., along the epistemological dimension) flowing from the individual to the group level (i.e., along the ontological dimension). The second flow of knowledge (vector #2) is theorized to occur through a process termed *externalization*, which denotes the use of metaphors through dialog that leads to articulation of tacit knowledge and its subsequent formalization to make it concrete and explicit.

The third flow of knowledge (vector #3) is theorized to occur through a process termed *combination*, which denotes coordination between different groups in the organization—along with

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documentation of existing knowledge—to combine new intra-team concepts with other, explicit knowledge in the organization. The fourth flow of knowledge (vector #4) is theorized to occur through a process termed *internalization*, which denotes diverse members in the organization applying the combined knowledge from above—often through trial and error—and in turn translating such knowledge into tacit form at the organization level.

UNDERSTANDING-FLOW DYNAMICS

This section begins by building upon Nonaka's theory to conceptualize an extended model of the knowledge-flow phenomenon. In keeping with the military focus of this technical report, we refer instead to this phenomenon as *understanding flow*.

Building upon Current Theory

The first step toward building upon current knowledge-flow theory pertains to the concept from above of a KM life cycle. We propose to augment Nonaka's two-dimensional framework through incorporation of this third dimension, and we operationalize the construct using the life-cycle stages from the Amalgamated Model described above (i.e., creation, organization, formalization, distribution, application, refinement). Further, because the concept *flow* is inherently dynamic, we also extend this framework through incorporation of *time* as a key, fourth dimension. Such augmented dimensionality preserves—and indeed subsumes—the two-dimensional framework proposed through current theory, and it provides the basis for a richer model, which may enhance our descriptive and explanatory power in terms of understanding the understanding-flow phenomenon.

The second step toward building upon current knowledge-flow theory pertains to the epistemological dimension theorized above, as it includes only binary states (i.e., tacit, explicit). In contrast, we propose that understanding fills a continuum along the dimension characterized by tacit and explicit endpoints. Thus, instead of a simple contrast between explicit and tacit understanding, this would enable us to trace understanding as it flows through a continuous *range* of explicitness. We defer operationalization of the concept *explicitness* until the empirical, field-study section below, but a continuous dimension makes for a richer model than—and indeed subsumes—one with only two binary states.

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This same rationale can be applied to the ontological dimension theorized above, as it supports only a few granular states (e.g., individual, group, organization). In contrast, we propose that understanding may fill a continuum along the dimension characterized by how many people are reached by the understanding (e.g., at a particular level of explicitness, life cycle phase). Operationalization of this *reach* concept is similarly deferred to the field-study section below, but tracing understanding flows across a continuous dimension similarly makes for a richer model than—and indeed subsumes—one with only a few discrete states.

A third step toward theory building stems from the research noted above that differentiates between vertical processes and their horizontal-process counterparts in terms of enabling knowledge versus work flows, respectively. Such differentiation is simply absent from current theory. But it highlights an important, cross-process focus of understanding flow, and it may help explain the mechanics associated with prior theory (e.g., Nonaka's concepts of socialization, externalization, combination).
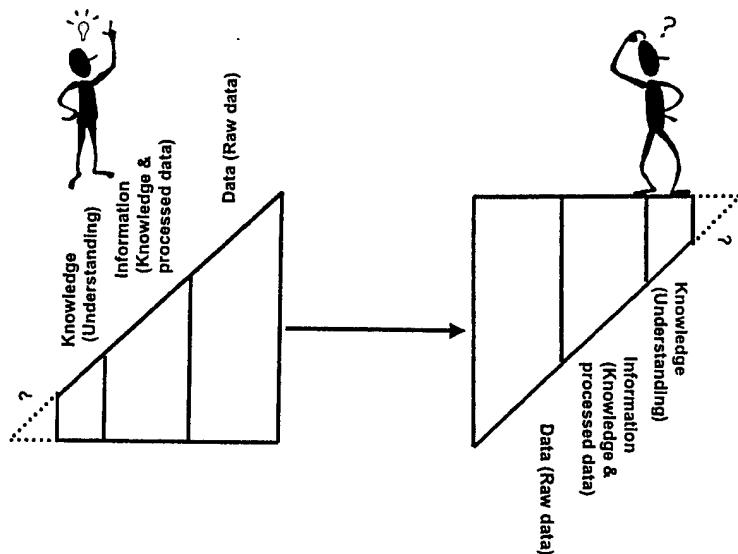

Figure 4. Layered Understanding Transfer

A final step toward building upon current work addresses the mechanics of understanding flow. If one accepts that knowledge[1] is distinct from—yet related to—information and data, flow concepts such as *socialization* and *externalization* seem quite incomplete, as they fail to recognize the respective roles of data (e.g., words used to share experiences), information (e.g., conveyed through metaphors and dialog) and knowledge (e.g., capability and expertise shared across individuals).

Drawing an analogy from the International Organization for Standards (ISO) data-communications model (Panko 1997)—which has seven layers involved with *data* communication (i.e., flow) between any two computer applications—we conceptualize understanding to similarly pass through successive layers. And drawing from the cognitive-hierarchy discussion above, we propose the mechanics of understanding flow as beginning with conversion from knowledge[2], through information, to data in one agent (e.g., Agent A, human or machine). The data are then transmitted through some media (e.g., network, voice, handwritten page)—according to the ISO model—and the flow in some other agent (e.g., Agent B) is reversed—from data, through information, to knowledge. This is depicted in Figure 4, which explicitly distinguishes between data, information and knowledge associated with the flow.

One key insight is consistent with our NCW quotation in the introduction: the flow of understanding is not the domain of networks and communications. Rather, it lies squarely in the (vertical) *processes* that agents (e.g., human, machine) use to convert understanding for, and transfer it across, such networks and communications. This may have major implications in terms of how we design information systems to automate and support understanding flow in the enterprise.

This insight also helps resolve the apparent tension between advocates of knowledge hierarchies with data on the "bottom" (cf. Davenport and Prusak 1998, Nissen et al. 2000, von Krough et al. 2000) versus data on the "top" (cf. Tuomi 2000). In short, understanding flow can be visualized as progressing "down" the first hierarchy—knowledge to information to data—and then conversely progressing "up" the second hierarchy—data to information to knowledge. Whether the hierarchy has data on the bottom or data on the top, therefore, would simply depend upon one's perspective (e.g., as producer or consumer of understanding).

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[1] Recall our business/military mapping: knowledge maps to understanding; information maps to knowledge and processed data; data maps to raw data.

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An Extended Model of Understanding Flow
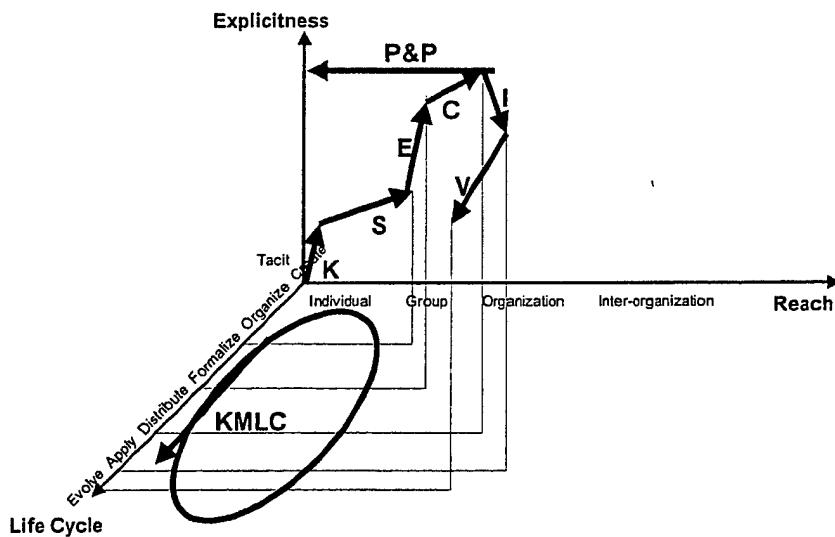
Figure 5. Extended Model with Understanding Flows

The theory building from above provides the grist from which to develop an extended model of the understanding-flow phenomenon. In Figure 5[3], we note a few, notional, understanding-flow vectors for illustrating and classifying various dynamic patterns of understanding as it flows through the enterprise. For instance, the simple linear flow labeled "P&P" depicts the manner in which most enterprises inform and train employees through the use of policies and procedures: explicit documents and guidelines that individuals in the organization are expected to memorize, refer to and observe. As another instance, the cyclical flow of understanding described by the amalgamated KM life cycle model from above, depicted and labeled as "KMLC" in the figure, reflects a more-complex dynamic than its simple, linear counterpart. And as depicted, this latter flow delineates a cycle of understanding creation, distribution and evolution within a workgroup, for example.

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[2] Again, with our business/military mapping, this conversion would be from understanding, through knowledge/processed data, to raw data, and so forth.

[3] Because Nonaka's terminology for the dimensions reflected in Figure 3 can lead to confusion (e.g., with respect to use of the terms *epistemological* and *ontological*), we substitute the term *explicitness* for *epistemological* and *reach* for *ontological* in Figure 5.

Further, Nonaka's dynamic flow theory can also be delineated in this space by the curvilinear vector sequence K-S-E-C-I. Referring back to his model above, these vectors correspond to the processes termed *creation, socialization, externalization, combination* and *internalization*, respectively. From this, our model subsumes the one proposed by Nonaka, and it reveals a somewhat-complex dynamic as understanding flows along the life cycle. Moreover, examination of this space suggests also including the "R" vector *(refinement)*, which is not part of Nonaka's theory but represents a key element of the empirically derived Amalgamated Model (e.g., key to knowledge evolution). Clearly, a great many other flows and patterns can be depicted in this manner. We employ this vector-space approach to depicting and visualizing understanding flows in the field study below.

JTF FIELD STUDY

In this section, we report the findings from field research, most of which takes place afloat on naval warships conducting military operations at sea. Clearly, this is where many key activities (e.g., situational awareness, tactical decision making, strike execution, damage assessment) associated with military processes take place, and one cannot attempt to understand the complex environment that corresponds without direct observation. In this field study, such direct observation takes place onboard the USS Alpha[4], flagship for the Navy's Bravo Fleet. The Commander of Bravo Fleet, a Vice Admiral (i.e., with three "stars"), has assumed the role of Joint Task Force Commander (CJTF) for Operation DELTA WATCH, which places him in charge of combined combatant forces from the Army, Air Force, Marines and Navy. This is the significance of the term *joint* above (i.e., joint forces).

Following the terminology of Yin (1994), we undertake a Type I field study (i.e., single case, single unit of analysis). The case represents an extreme one, however, so we anticipate obtaining informative findings even from this one study. The single unit of analysis is that of the joint task force, as managed by the CJTF. The case itself focuses on one JTF operation (i.e., DELTA WATCH). This JTF and operation is representative of contemporary military organizations and processes in action, so generalization to other commands and operations should be straightforward.

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[4] Because many aspects of military processes are classified, this field study report employs fictitious names for most specific operations, ships, weapons, capabilities and tactics. This should not detract from our ability to attain insight into the manner in which understanding flows through the associated processes.

The investigator employs multiple approaches to data acquisition in this study. Again following Yin, this allows for triangulation between observations and promotes reliability of the results. Such multiple approaches center on direct observation, as the investigator has access to the CJTF from the flagship ALPHA and can fly by helicopter to interact with any of the combatants. The investigator also serves as a participant observer in many respects, as he obtains an official position on the CJTF Staff and interacts on a continuous and direct basis with JTF personnel (e.g., through briefings, watches, meals, quarters, exercise, port calls, social events). After an initial period of familiarization, socialization and acculturation, the investigator becomes an "insider."

Further, the investigator has access to what Yin calls an "informant." Because the term *informant* has a particularly unsettling connotation in the military setting, we describe our relationship with this well placed officer on the CJTF Staff as a strategic contact. This relationship is helpful for interpretation of many military-specific terms, procedures and activities, with which the investigator is initially unfamiliar. Other approaches to data collection include document review, and the investigator conducts semi-structured and unstructured interviews with the JTF Commander, his Chief of Staff and all Assistant Chiefs of Staff, as well as many other key people onboard the ALPHA and other ships (e.g., the aircraft carrier USS Charlie, amphibious platform USS Echo). In total, the investigator spends roughly three months directly studying this case. And following the associated field research, the investigator engages in several follow-on conversations with key personnel to validate and refine the findings.

The Setting

U.S. Military JTF operations are very attractive for field research, as they appear to be quite extreme in terms of understanding-flow demands. Indeed, we refer to the Military as a very large enterprise (VLE) for this reason. For instance, a particular military operation can involve many dozens of ships at sea, many hundreds of aircraft, and many thousands of people spanning enormous expanses of ocean. And through joint operations such as DELTA WATCH, the scale can further include people, tanks, equipment and operations ashore, as well as land-based aerial assets and satellites in various orbits.

Planning and coordination of such a large, geographically dispersed and diverse military force represents an information-intensive activity, and the time-critical nature of military operations (e.g., need

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for coordinated attacks, simultaneous air, land and sea defenses) places an additional burden on such planning and coordination. The hazardous context, within which military operations are conducted, adds to the extreme nature of this case, in that penalties for poor decisions and execution errors can include injuries, deaths and political ramifications. The myriad distributed people participating in a JTF operation need to know what missions they are supposed to complete, when and where they are supposed to complete them, with whom and with which weapons they might best be completed successfully, and how to perform their specific mission tasks.

In many respects, these requirements are similar to the kinds of management and professionalism required for effective processes in business or government. For instance, executives, managers and knowledge workers in business firms and governmental agencies must similarly understand what needs to be accomplished, where, with whom and how to accomplish it, and so forth. Thus, many of our results are expected to generalize beyond just military processes. But one aspect of this management and professionalism is clearly extreme in this case under study: timing; that is, all of the plans, people, machines and other factors must be in place and come together *at the same time*[5].

In terms of understanding and its flow through the JTF enterprise, the implication is, substantial military understanding must complete its required flow through the enterprise by a specific point in time (e.g., the launch of an attack). As one experienced aviator describes, there's no time for learning your craft when flying an F/A-18 jet at 500 knots, 50 feet above the ocean surface, heading into hostile territory (e.g., confronting surface-to-air missiles) on a strike sortie. Indeed, if we can effectively address understanding flow in this extreme case of the JTF enterprise, adapting understanding-flow techniques and technologies to less extreme enterprises (e.g., peace-time military operations, business and governmental enterprises) should be quite feasible.

The setting of this investigation includes two large naval formations: 1) a carrier battlegroup (CVBG) and 2) an amphibious ready group (ARG). The CVBG includes a full-size aircraft carrier, which is large enough to launch and recover fixed-wing jet aircraft (e.g., fighter, attack, surveillance), and a host of support vessels (e.g., cruisers, destroyers, submarines) to make up an ensemble for conducting offensive and defensive maritime and air operations. The ARG includes a smaller carrier, which is used to launch

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and recover rotary-wing aircraft (e.g., attack, anti-submarine, transport) and amphibious-landing craft, along with its own complement of support vessels. The primary mission of the CVBG is power projection and to establish military superiority (esp. air and maritime), as it is designed and trained for strike, intercept, anti-submarine and maritime-interdiction missions. The ARG is principally employed for invasion purposes, as it is designed and trained to get Marines ashore for expeditionary warfare. With this investigation addressing joint operations, several Air Force squadrons, a number of Army units and foreign militaries also participate, but we focus in particular on sea-based forces (i.e., the CVBG and ARG).

Operation DELTA WATCH is conducted in international waters, with operational areas extending hundreds of miles from East to West and nearly a thousand miles from North to South. Adjoining international waters are territories of several different countries—allied, neutral and (potentially) hostile. Each country represents a sovereign nation, and each has its own air, land and naval forces in the area. In all, the operational area may have several hundred *contacts* (e.g., aircraft, ships, submarines)—identified on tactical and operational displays as "friendly," "hostile" and "unidentified"—at any one time, including civilian and commercial planes and ships, in addition to their military counterparts.

Identifying, interrogating, keeping track of, and responding to such a large number of contacts exceeds the bounded rationality of any single individual, yet the CJTF strives to have all units and personnel "speak with one voice," "act with one intention," and "move as one unit." This is very challenging for such a large, geographically dispersed enterprise that operates at sea (e.g., without land-based communications infrastructure), oftentimes in hostile waters. In terms of understanding understanding flow through this VLE, we focus our attention on the understanding required to enable coordinated and effective military operations through DELTA WATCH.

Key Understanding Elements

Through our immersive field study methods outlined above (esp. participant observation, strategic contact, semi-structured interviews), we identify and gain insight into four key elements of understanding required for the JTF enterprise: 1) understanding about contacts in the operational area (e.g., friendly/hostile, speed/heading, offensive/defensive capabilities), 2) understanding of the operational area itself (e.g., geography/waters, geopolitics, weather), 3) military combat understanding (e.g., combat tactics, weapons,

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[5] Indeed, the military uses a 24-hour clock set to *Zulu Time* (i.e., Greenwich Mean Time) to synchronize forces around the world.

unit synchronization), and 4) understanding to plan military operations (e.g., intelligence implications, battle/campaign strategies, mission profiles). Some of these aspects can be satisfied with explicit understanding, and information technologies such as digital communication networks, decision support systems and groupware are employed to support the corresponding understanding flows. Others, however, rely principally upon tacit understanding—which resides within the minds and bodies of experienced, individual people—and are not as conducive to IT support.

Table 2. Three Dimensions of the Key Understanding Elements

Understanding Element	Explicitness	Reach	Flow Time
Contacts	Comprehend	Interorganization	Hours
Operational area	Synthesize	Organization	Weeks
Combat	Memorize	Individual	Years
Op Planning	Evaluate	Group	Decades

Using the framework developed above, we classify each of these key understanding elements according to three dimensions: 1) *explicitness*, 2) *reach* and 3) *flow time*. Table 2 summarizes this classification. We first take steps toward operationalizing these dimensional constructs. We then use such constructs to classify and describe the four key understanding elements.

Operationalization

As noted above, we theorize the dimension *explicitness* in terms of a continuum, but we presently lack an appropriate scale or instrument for effective operationalization as a measurable construct. Alternatively, we can operationalize understanding in terms of *actions* that it enables (e.g., correct decisions, appropriate behaviors). For instance, we can draw from research on learning (i.e., understanding transfer) and pedagogy (Bloom 1956) to identify six, increasingly tacit states of understanding—operationalized through enabled actions—that can be mapped to this dimension: 1) memorization, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation. We anticipate being able to differentiate between these six explicitness levels when describing various understanding flows in the field.

As also noted above, we theorize the dimension *reach* in terms of a continuum. And if we define this construct in terms of the number of people associated with a particular understanding flow (e.g., at a specific level of explicitness, at a specific stage of the life cycle), then we should be able to construct a numerical scale for measurement in the field. In the case of military forces at sea, however, the enterprise is

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organized through highly structured and cohesive units (e.g., squadrons), departments (e.g., Operations), vessels (e.g., USS Charlie) and formations (e.g., CVBG). Thus, the course granularity of Nonaka's operationalization scheme—in terms of unit size (e.g., individual, group, organization)—appears to be more informative than the number of people in a particular organization, so we stay with this former approach to operationalizing the reach dimension in this study.

Flow time is used to denote the length of time required for various types of understanding to flow from one point to another through the enterprise. Although the dimension *time* has long supported direct measurement using continuous, numerical scales (esp. in the physical sciences), in terms of military understanding flows observed in this study—many of which require long periods of time—we can only gauge relative orders of magnitude in terms of flow time. Operationalization of *flow time* is therefore effected in granular terms such as *hours, days, weeks, months, years, decades* and *generations.*

Understanding Element Classification and Description
Returning to the key understanding elements summarized in Table 2, understanding of contacts is quite explicit, and most such understanding is directly associated with interaction between people and information systems. For instance, the speed, heading and capabilities of hostile and friendly contacts need to be comprehended. This understanding supports the situational-awareness process, which is similar to the kind of environmental scanning activity long discussed as critical in the business context of executive information systems (EIS). However, this comprehended understanding must be shared by practically all JTF participants, groups and organizations in a theater of operations for such a large force to coordinate its plans and activities. In terms of flow time, use of sensors and information systems facilitates development and distribution of a common operational picture within a matter of hours. This first understanding element is plotted as symbol "1" in Figure 6 for reference and illustration; that is, this symbol is plotted at the *comprehension* level along the explicitness axis, at the *inter-organization* point of the reach dimension, and at the *hours* magnitude in terms of flow time.
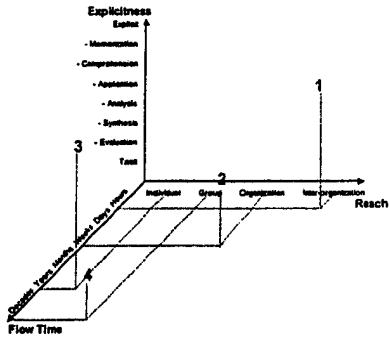
Figure 6. Plotted Understanding Elements

Regarding understanding of the operational area, this is far more tacit in nature than its contacts counterpart from above. The surrounding geography (e.g., mountains, deserts, ports), ocean conditions (e.g., currents, depths, salinity levels), geopolitical situations (e.g., strained foreign relations, hostilities, · popular unrest) and weather forecasts (e.g., cloud cover, visibility, moonlight illumination) must all be synthesized together into a cohesive understanding of the environment in which operations are being conducted. Because each unit in the JTF (e.g., Navy ship, Air Force wing, Marine expeditionary unit) performs a different role (e.g., anti-submarine, strike, invasion), the nature of this understanding necessarily differs, so we plot this at the organization level along the reach axis (see symbol "2" in the figure). For instance, ocean temperature and salinity are critical to hunting enemy submarines but irrelevant to aerial bombardment. In terms of flow time, operational area understanding can complete its flow through a particular organization (e.g., naval ship, fighter wing, expeditionary unit) in a matter of weeks, as sailors, officers and commanders acquire local experience in each theater of operations.

Regarding understanding of combat, this is principally explicit[6], the content of express military doctrine and techniques that are studied and memorized in military academies, training schools and war colleges. This understanding is also specific to each job and applicable at the individual level, as everyone

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[6] Combat knowledge also includes a tacit component, the flow of which is differentiated in the section below through decomposition into vertical processes.

has a particular responsibility in a military operation and is expected to perform accordingly and effectively. This, execution-oriented understanding generally takes years to acquire and develop, with the corresponding point plotted as symbol "3" in the figure.

Alternatively, understanding of operational planning begins as a creative activity. It takes place in relatively small groups (e.g., comprised of the CJTF, combatant commanders, key staff members such as Intelligence and Operations), as alternative plans and courses of action are synthesized. However, the understanding-intensive focus of this activity involves more refinement and evolution of plans than creation, as the group is engaged in constant evaluation. Much like a chess master is always contemplating many possible courses of play and thinking several moves in advance of the current board position, this military understanding is highly tacit and subject to iterative re-evaluation. This understanding element is plotted as symbol "4" in the figure. Notice that decades are required for such understanding to develop in JTF "executives" (i.e., admirals, generals).

This summarizes the key elements of understanding and classifies them according to our three-dimensional framework[7] to provide a picture of understanding in the JTF enterprise. Notice, the four key understanding elements identified for study are widely distributed throughout our three-dimensional representational space. Such wide distribution helps ensure that we address a variety of diverse understanding flows in this study.

Vertical Processes and Understanding Flows
In this section, we discuss vertical processes and understanding flows corresponding to the four key understanding elements outlined above. Such processes and flows associated with each understanding element are addressed in turn.

Contacts Understanding
When the JTF first arrives in a new theater, some of the key understanding elements from above are already in place, whereas others need to be developed nearly from scratch, and some fall in between these extremes. At one extreme is contacts understanding. Before the JTF arrives in a theater of operations, it has very little information pertaining to contacts in the area, as such an area can be half a world away and well

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[7] Because it is difficult to effectively represent more than three dimensions at a time through static, black-and-white displays (e.g., graphs), we limit our depiction of any particular knowledge flow to three dimensions. In the section that follows, however, we

out of sensor range. The task force is not completely "blind," however, as the military's Foxtrot system

provides global sensor feeds to ships, planes and land units. But such Foxtrot inputs are incomplete, and

the JTF cannot establish situational awareness until it arrives in theater and begins to make and analyze

contacts with its own sensors.
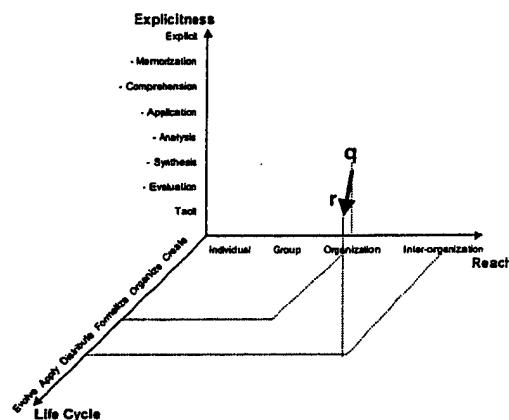
Figure 7. Contacts Understanding-Flow Vectors

The JTF also receives intelligence reports pertaining to contacts in the theater, which can be

disseminated securely using the Golf network. But intelligence reports outside the JTF itself tend to be

viewed with some suspicion, and JTF commanders do not seem to feel confident about their understanding

of contacts until they arrive in theater and begin their own intelligence operations. As a note, this cultural

pattern appears to be independent of organizational size. For instance, with respect to such intelligence

reports, a large aircraft carrier with 5000 people onboard (i.e., one organization) is likely to behave in a

manner very similar to that of a much-smaller ship (e.g., a frigate) with only a fraction of the number of

people onboard. This serves to reinforce our preference for Nonaka's granular *reach* operationalization

over use of a continuous scale (e.g., number of people).

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substitute the dimension *KM life cycle* for *flow time*, which provides a complementary perspective to the elements plotted in Figure 6.

The vertical processes associated with the flow of contacts understanding center on information technology and intelligence operations. The information technology employed to drive this understanding flow is quite formal, in that official systems (e.g., sensors, networks, applications) are employed. However, observation of JTF officers conducting what they term the *battle watch*—through which the overall course of Operation DELTA WATCH is monitored and directed—we also identify information technology being used in a less formal manner. For instance, (encrypted) e-mail messages are routinely sent across the Golf network between ships at sea, and all of the larger ships (e.g., carriers, communications ships, command ships) have (classified) Web servers that are used to organize and disseminate information among JTF participants. Additionally, conversations with one Battle Watch Captain (i.e., our strategic contact) indicate several (secure) "chat rooms" are employed to discuss various aspects of operations across wireless networks at sea. Unlike the formal systems above, these latter uses of IT are relatively informal, in that the associated processes have emerged organically, as opposed to being designed for use and officially sanctioned.

As noted above, contacts understanding is very explicit in nature, requiring comprehension by JTF personnel, but it must be disseminated JTF-wide in order to support a common operational picture. In Figure 7, we delineate the corresponding understanding flow as beginning with creation of new contacts understanding at the organization level (point "q") through synthesis of sensor data and intelligence information, with an organization in this case representing an individual ship (e.g., the ALPHA, CHARLIE, ECHO). This understanding is then organized according to a common geographical display format and distributed across the various JTF organizations to be comprehended (point "r").

In terms of understanding flow, this vector is relatively simple when compared to those discussed below, but such contacts-understanding flows are critical to effective task-force operations nonetheless. Notice from Figure 7, the flow of contacts understanding remains at the levels of organization and inter-organization in terms of reach, whereas some other understanding flows, discussed below, occur principally at the individual and group levels. Contacts understanding is also quite explicit, whereas some other understanding flows are more tacit in nature. Further, contacts understanding does not begin to flow until the JTF arrives in its theater of operations, and the time required is relatively short, whereas the time

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required for some other understanding flows is much longer and must be completed before such arrival. As noted above, the contacts-understanding element represents one extreme in terms of understanding flow.

Operational Area Understanding
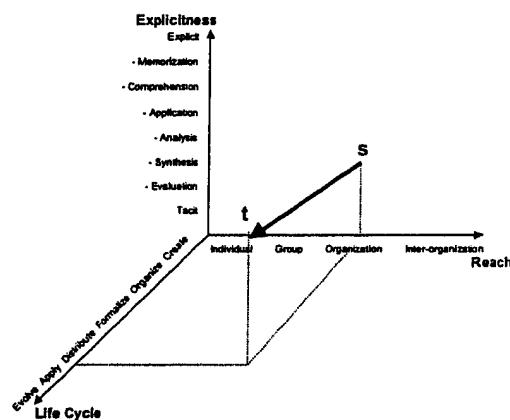
Figure 8. Operational Area Understanding-Flow Vectors

Understanding flows pertaining to the operational area are similar to those described above with respect to contacts, in that much of this flow does not begin until arrival in theater. However, the information that supports synthesis of understanding about the operational area lends itself to easy distribution via network, so JTF personnel are not required to wait until their arrival in theater. Indeed, discussions with JTF personnel indicate informal IT (e.g., e-mail, Web, telephone) is used for this very purpose. In either case, the synthesis takes place at the organizational level and involves the creation of new understanding: a composite picture of the operational area. The understanding associated with this element is described by a simple vector (i.e., s-t) in Figure 8, as operational area understanding is simply created and distributed at the organizational level.

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Combat Understanding
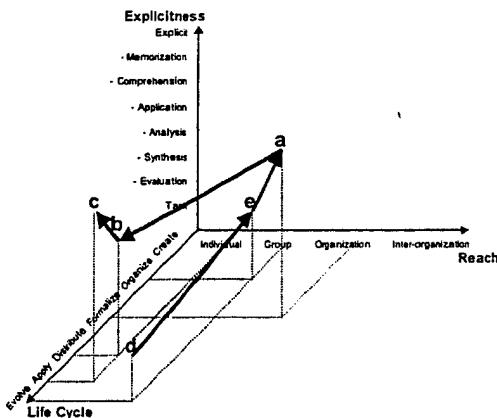
Figure 9. Training Understanding-Flow Vectors

At the other extreme is combat understanding. The flow of military combat understanding possessed by individuals in the JTF must already be complete when the JTF arrives. Indeed, each individual JTF participant is selected, based on his or her specific combat understanding, before the task force even assembles and sets sail toward the theater. Although some new combat understanding is acquired during each operation (i.e., some learning occurs), the amount of such new understanding is very small when compared to the stores brought to the theater by each individual. Thus, the flow of such understanding *during* the operation—a horizontal process—is negligible with respect to the counterpart flows required to prepare each warrior for such an operation—a set of vertical processes. Using a manufacturing term, we may therefore refer to this as an *inventory model of understanding flow*, for one must anticipate and develop the levels and kinds of understanding that will be required well in advance of their application.

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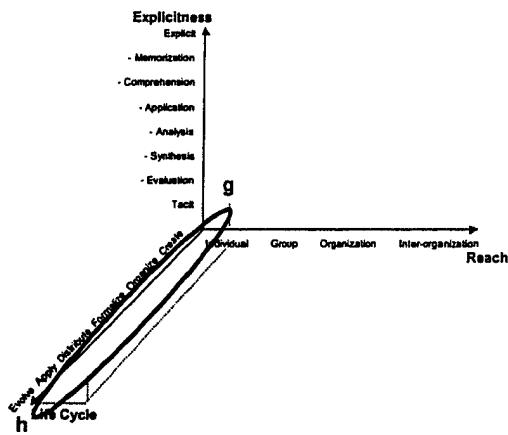
Figure 10. Experience Understanding-Flow Vectors

The vertical processes used to develop such military-specific understanding include training (e.g., military schools), experience (e.g., operations at sea), mentorship (e.g., close and sustained interaction with more experienced warriors) and assignment (e.g., selection of the right person for each job). In terms of our three-dimensional schema for tracking understanding flow, each of these vertical processes has a unique vector associated with it.

The first vector, delineated by the points "a," "b" and "c" in Figure 9, is associated with training. Training represents the distribution of explicit understanding from an organization to the individual (a), who must first learn to apply it in the training environment (b) and then commit it to memory for application in the field (c). Also shown in this figure is the complementary vector associated with organizational learning. At least in the JTF, such complementary understanding flow generally involves evaluation of current and previous operations by a group of people (e.g., in an after-action review), who are essentially refining existing understanding (d). Such refinement can lead in turn to creation of new understanding, which is organized by the group (e) to synthesize new doctrine and then formalized (i.e., made explicit) for distribution by the organization (a).

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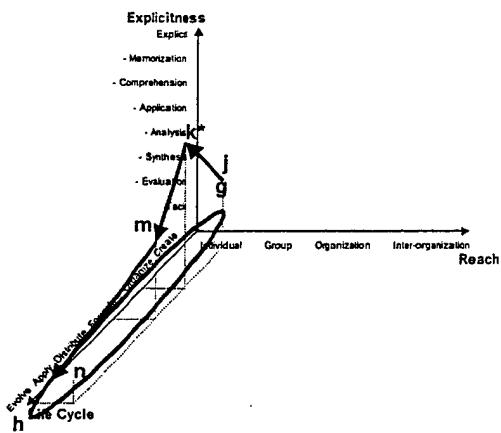
Figure 11. Mentorship Understanding-Flow Vectors

The next vector, delineated by the points "g" and "h" in Figure 10, is associated with experience

and commonly referred to as on-the-job training (OJT). This process is highly valued in the military, as

experience often counts more toward being selected for specific jobs and assignments than does education,

training, personality or most other qualifications do. We do not understand the mechanics of this flow

nearly as well as those pertaining to training above, as the understanding associated with experiential

learning is highly tacit, and the associated cognitive processes are more the domain of psychology and

learning theory than information systems. But following Nonaka, such tacit understanding is presumed to

begin with creation at the individual level, and we delineate the understanding-flow vector following the

life cycle through refinement and evolution in the figure. In essence, we view this as a *cycle* of

understanding—which remains tacit at the individual level—passing through various steps of the life cycle

repeatedly.

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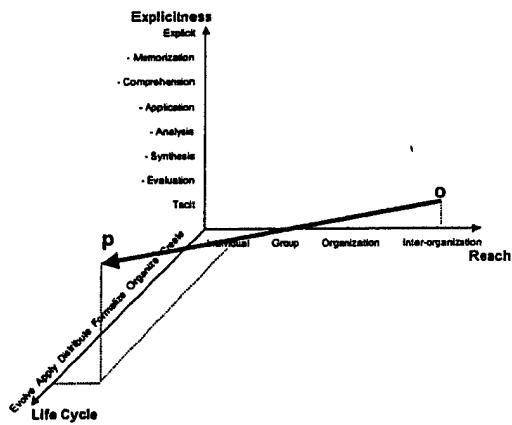
Figure 12. Assignment Understanding-Flow Vectors

The next vector, delineated by the points "j," "k," "m" and "n" in Figure 11, is associated with mentorship. It is common for commanding and senior officers onboard ship to critique the decisions and actions of junior officers, for instance, providing guidance for learning important techniques and templates for improving their performance. The most common manifestation of such mentorship in the JTF is dyadic in nature and occurs between pairs of individuals of different rank. This represents a flow at the individual level, but it takes place between one individual (e.g., senior officer) and another (e.g., junior officer) as delineated in the figure. New understanding to be acquired by the junior officer is first created through the mentor's evaluation (j). The protégé must comprehend and organize the understanding associated with the mentor's critique (k). We highlight the k point with an asterisk (i.e., "k*") to note this involves a *different* individual than that corresponding with point "j." From here, discussions with people onboard the ALPHA suggest a cycle of formalization and synthesis (m), application, refinement and evolution follows, with the associated understanding becoming increasingly tacit as it flows (n). Once this becomes internalized as part of the junior officer's understanding base, participants onboard ship describe it as combining with the officer's experience (i.e., OJT) and converging with the understanding-flow vector delineated in Figure 10

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above (see cyclical vector between points "g" and "h"). Thus, we find that understanding flows from different vertical processes (e.g., experience, mentorship) clearly interact with one another. But this latter flow does not initiate until the mentor evaluates the protégé's performance and provides a critique.

Finally, the vector delineated by points "o" and "p" in Figure 12 is associated with assignment. Here, tacit understanding, possessed collectively by people throughout the enterprise (o), flows along with the individual person (p) assigned to each specific job (e.g., to be applied in some other part of the enterprise). In essence, this vertical process identifies which individual(s) in the enterprise is best qualified to apply his or her understanding to a specific job/assignment. As above, we find a clear interaction between various vertical processes and their associated understanding flows.

Looking back across these four figures and the flows corresponding to the vertical processes associated with the understanding element of combat, one can observe several different dynamic patterns. The vectors delineate various directions in the explicitness dimension (e.g., tacit to explicit, explicit to tacit) that are associated with these flows, which serve to reinforce one part of Nonaka's dynamics of understanding flow. And the vectors trace understanding as it traverses several reach levels in the enterprise, also reinforcing a part of Nonaka's theory. But the flows further follow the life cycle stages proposed by Nissen et al.—particularly where understanding remains tacit as it flows, such as through vertical processes of experience, mentorship and assignment—which serves to support some aspects of KM life cycle models.

These understanding flows do not correspond to the theoretical models closely, however, suggesting that such models require additional development and refinement before they match empirical findings. For instance, although the vectors cross several tacit and explicit levels and different degrees of reach, as proposed by Nonaka, they do not follow the specific sequencing and dynamics he discusses (e.g., socialization, externalization, combination). Similarly, the understanding-flow vectors span multiple life cycle stages (e.g., create, organize, formalize), but they do not pass through all of them, in a consistent sequence, or even unidirectionally. Hence, this differs from the customary characterization of such flows in most life cycle models.

Operational Planning Understanding

Operational planning is quite similar to combat in terms of the vertical processes that drive the associated understanding flows, because people must master combat early in their careers before ever getting a chance to engage in operational planning. Thus, the (vertical) training, experience, mentorship and assignment processes from above all contribute toward effective operational planning capabilities as well, and the corresponding understanding flows are well represented by the vectors delineated through the combat figures (i.e., Figures 9 – 12).

However, operational planning involves new-understanding creation, whereas combat is far more-applied in orientation. Also, operational planning is generally accomplished in small groups, whereas combat understanding is principally associated with the individual. Thus, the understanding flow associated with the *group's* operational planning capability involves an additional dynamic that augments combat flows. Before the group can create and evaluate military plans for the task force, its members must learn to work together effectively, develop a common set of terms, and establish the processes that will be used to develop the plans.
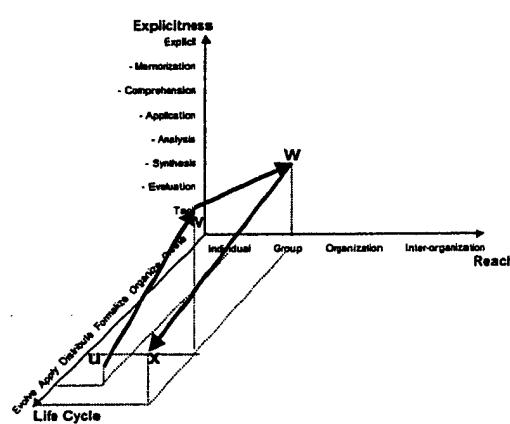
Figure 13. Operational Planning Understanding-Flow Vectors

In essence, such operational planning understanding pertains to a virtual organization (e.g., comprised of the CJTF, combatant commanders, others) that comes together for the JTF operation. From our observations at sea, the group's formal leader (i.e., the CJTF) begins this virtual organizing through the vertical process of leadership, which drives tacit understanding and is done as an individual (point "u" in Figure 13). This leadership understanding is used to formulate an approach for communicating with other group members and enlisting their active participation in the planning process. Understanding about what is expected of the other members is deeply rooted in military culture and tradition, which all members bring with them to the JTF operation[8]. The leader's communication can be viewed more as filling in a template with specific information than transferring understanding per se, but the group members must comprehend and be able to apply the leader's suggestions for how the group is to perform (point "v"). Working together, the group then applies its collective tacit understanding to synthesize some alternative plans and courses of action (point "w"), which then become the focus of continuous evaluation and refinement (point "x"). As can be seen from the corresponding vectors delineated in Figure 13, this latter vertical process of leadership has its own characteristic pattern of understanding flow. Notice, IT is not included among the vertical processes driving understanding flow for this planning element. This may represent an opportunity in terms of IT application.

Summary
To summarize, the key vertical processes found to drive understanding flow in the JTF are diverse, as are the corresponding understanding-flow vectors. In examining the four key elements of understanding above (i.e., contacts, operational area, combat, operational planning), we identify nine vertical processes that are associated. These are listed in Table 3. Notice, only two of the four key understanding elements are associated with IT-enabled vertical processes: contacts and operational area.

Understanding flows driven by the nine vertical processes are summarized in Figure 14 for reference, as we combine the plots of all the understanding-flow vectors from above. This provides some insight into the overall pattern of understanding flow in this JTF enterprise. The four vectors associated

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[8] Military acculturation can also be viewed as a vertical process. But it is difficult to observe and interpret through this study, so we do not attempt to include or diagram it here.

with combat understanding flows are delineated by dotted lines, and most of these vectors flow at the

individual level. Recall, only the assignment vector (i.e., o-p) involves reach levels beyond the individual.

This visual pattern supports our initial characterization of combat understanding as being principally

individual in nature. The vector associated with operational planning (i.e., u-v-w-x) is delineated with a

dashed line to provide some contrast. Notice, this vector runs within those associated with combat,

suggesting the corresponding sets of understanding are quite similar in terms of their flow through the

enterprise.

Table 3. Key Understanding Elements and Vertical Processes

Key Understanding Element	Associated Vertical Process
Contacts	Information technology, intelligence operations
Operational area	Information technology, synthesis
Combat	Training, experience, mentorship, assignment
Operational planning	Training, experience, mentorship, assignment
	Leadership, evaluation
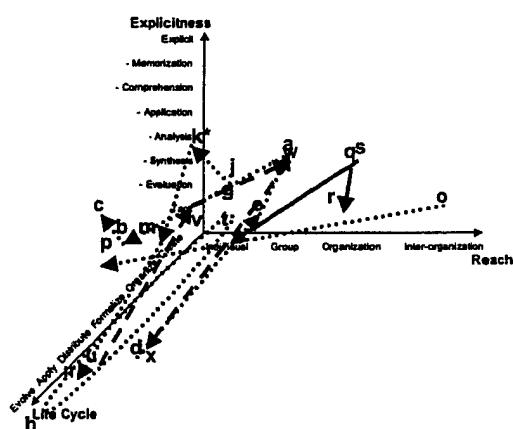
Figure 14. Combined Understanding-Flow Vectors

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Alternatively, the vectors associated with contacts (i.e., q-r) and operational area (i.e., s-t) are delineated with solid lines and reveal a very different pattern of flow through the enterprise. This latter understanding-flow pattern occurs much further out along the reach axis than the others, and the associated understanding is more explicit overall. These contacts and operational area understanding flows also span a smaller portion of the life cycle dimension than their combat and planning counterparts. Interestingly, drawing from our summary in Table 3 above, notice that these latter understanding flows are well supported by information technology as vertical processes, whereas the former flows are not. Thus, we are beginning to establish a correspondence between understanding-flow patterns—which can be examined visually through vector plots—and the kinds of vertical processes that drive them. This represents the beginning of a contribution to be made through the present study.

CONCLUSIONS AND FUTURE RESEARCH

Network-centric warfare emphasizes information superiority for battlespace efficacy, but it is clear that the mechanics of how knowledge flows are just as important as those pertaining to the networks and communication systems used to transmit data and information. Unfortunately, with the strong presumption that knowledge is distinct from data and information, knowledge-flow mechanics in the warfare context are not well understood; even the term *knowledge* is used in conflicting ways (e.g., to describe *information* flows) by NCW experts, operational personnel and developers of military doctrine. Mapping key concepts from technologically enabled business models—on which NCW is based in large part—to the military, we substitute the term *understanding flow* when discussing the mechanics of how knowledge flows in the NCW context. In one respect, this mapping and terminological substitution enable us to move forward and model knowledge-flow mechanics in a manner that is consistent with the operational Navy's lexicon; in another respect, however, it is clear that Navy lexicon does not yet include the term *understanding flow*. Hence, naval conceptualization of NCW may be missing a vital element.

Informed by recent advances in knowledge-flow theory, the research described in this technical report develops a four-dimensional model of understanding-flow mechanics. This multidimensional model enables a novel capability to recognize a variety of understanding-flow patterns found in the military enterprise, to distinguish such patterns from their counterparts pertaining to information and data, and to

enhance the speed and efficiency of NCW understanding flows. Just as understanding the mechanics of electrical flow is critical to developing useful electronic devices (e.g., amplifiers, integrated circuits), and understanding airflow mechanics is essential for designing useful aircraft equipment (e.g., engines, wings), understanding the mechanics of understanding flow is critical to conceiving useful NCW systems (e.g., "knowledge engines," "knowledge amplifiers"). To help make understanding-flow concepts and applications concrete, we employ our model of understanding flow to Navy-led, joint task force (JTF) operations at sea. The result is an increased understanding of understanding flow for network-centric warfare, which can be employed to guide the design of useful information systems, understanding-flow devices and business processes for military operations.

What are the key implications for commanders in the operational Navy? First, the rapid and efficient flow of understanding is critical to military performance in the NCW environment, but such flow is not the domain of networks and communication systems. Particularly where tacit understanding is concerned, it is clear that understanding flows through *people*, albeit such flow can be supported by IT. Hence, where commanders are concerned about military performance in the NCW environment, they must look first and foremost to the understanding possessed by their people, not the network and associated technology.

Second, the flow of work through a military enterprise (e.g., JTF) is distinct from, yet closely interrelated with, the flow of understanding through the enterprise. However, most commanders focus in detail on how work is progressing but pay little attention to how the corresponding understanding— understanding that *enables* the work to be accomplished—is flowing through the enterprise. Clearly, simple point measures such as *readiness* fail to capture the rich dynamics of understanding flow through the military enterprise. Indeed, one can envision the commander of tomorrow employing sophisticated tools (e.g., PERT networks, Gantt Charts) to track the progress of understanding flow, in addition to using such tools to track and manage workflow.

Finally, where the design of information systems and business processes is required to enable and support NCW, such design must take advantage of understanding how understanding flows through the military enterprise. By building upon the kind of research presented in this technical report, designers of information systems, business processes and even understanding-flow devices can now obtain a view into

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the mechanics of how understanding flows through the enterprise, and such view can effectively inform their design activities. As the informed-design process progresses, and we can obtain feedback on how well the designs serve their intended purposes in the NCW context, we must be vigilant about continuing to learn from such feedback and improving the theory underlying understanding flow. For such learning and theory can recursively continue to inform better the design process, and vice versa. This can lead to a virtuous cycle of discovery and application, the kind of cycle enabled by a strong partnership between the university (e.g., Naval Postgraduate School) and the Fleet (e.g., Third Fleet).

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